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Simple Computer Method Provides Contours for Radiological Images

An outline or a contour of any area that is defined by a change in density in a photographic film or a difference in intensity on a fluoroscopic screen can be generated by a newly developed method that is simple enough to be used with a small computer in a clinical environment. The method works best when high contrasts can be obtained; however, even a minimal amount of statistical averaging can provide a value for a mean gray level with a standard deviation of $\pm 1\%$ (about ± 0.3 in gray level), and thus it is highly probable that structures outlined by changes of about ± 0.6 in gray level (on a scale of 32) can be contoured.

As a preliminary step, the computer is provided with information concerning boundaries in the total image or of a section of the image; any of a number of methods may be used to supply the computer with a digitized image consisting of the x- and y-coordinates of a series of image points and the corresponding gray levels. In the basic computation method that has been developed, the gradient of each point in a digitized image is calculated with the aid of a threshold technique; then there is invoked a set of algorithms designed to reduce the number of gradient elements and to retain only the major ones for definition of the contour.

The first step in the process yields a picture function, $f(x,y)$, having a range of gray-level values from 0 to 31; the 32 levels correspond to the range of fluoroscopic brightness or roentgenographic densities found in the image to be processed. The second step involves a numerical calculation to obtain a modified gradient of $f'(x,y)$ for all values of x and y; directional derivatives for data points are calculated with the aid of a simple averaging technique from the brightness or densities of data groupings where each

point is at the center of a symmetrical set of nine (3×3) picture elements. Each point thus provides an expression for its gradient and, to obtain a contour, the matrix of gradient values obtained from the original picture function is examined for a selected minimum value. The latter operation is usually called "thresholding," and is frequently used to make features of greater brightness stand out, or even to outline areas. For the purpose at hand, the threshold is applied to the values of the gradient rather than to the values of $f(x,y)$, and a threshold value equivalent to about 4 gradient levels usually provides ample discrimination; thus, if the gradient of a picture element does not exceed 10% of the gray scale range, its value is set equal to zero. Although the above thresholding procedure produces contours which may be thick in some instances, resolution can be improved by reducing the number of picture elements retained in the gradient matrix (by an appropriate choice of algorithm parameters).

Noise spikes, artifacts, and other disturbances can be eliminated from the gradient matrix of the picture elements by a thinning algorithm that considers each value of the gradient function as the center point of a 3×3 array; each array is examined, and any value of the gradient function that has less than two non-zero values is set equal to zero at the end of this first segment of the procedure in order to eliminate isolated and peripheral elements. Then, all points that have four or more nearest neighbors which of themselves have more non-zero neighbors than the point being examined are set to zero; this algorithm is applied twice and followed by a gradient-maximum following-algorithm to eliminate all but the greatest values of the gradients remaining in the matrix.

(continued overleaf)

Notes:

1. The gradient-maximum following-algorithm operates as follows: each remaining point in the $g(x,y)$ matrix of the gradient of the picture elements is considered as the center of a 3×3 array of its nearest neighbors as done earlier. The maximum value of the nine gradients is compared to the value of the gradient under consideration; if the maximum value exceeds the gradient by three units, the point is zeroed. The derived contour is just the points remaining with non-zero values in the matrix representing $g(x,y)$.
2. Requests for further information may be directed to:
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